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White and red fir cone production in northeastern California: report of a 16-year study

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Cones on selected trees were counted for 16 years to determine crop sizes and periodicity. Nearby related studies of fir seedling establishment in several kinds of regeneration cuttings indicated that unless cone production reached an average of 45 cones per tree, seedling establishment was inadequate. Production at or above this level occurred most often at 1- or 2-year intervals; the widest interval was 4 years. When the average fell below this level, cone production from tree to tree was erratic.

Oxford: 174.7 *Abies concolor* [—232.11+174.7 *Abies magnifica*] +232.11—174.7 *Abies* spp.
Retrieval Terms: Abies concolor, Abies magnifica, red fir, white fir, seed production, Swain Mountain Experimental Forest, northeastern California.

Problems of management of true fir forests have been studied during the past two decades at Swain Mountain Experimental Forest in northern California. Early studies were designed to answer the most pressing silvicultural and management questions related to natural regeneration and the release of understory trees. Cone production, cone and seed damage, and seed dissemination were studied in their relationship to seedling establishment on prepared seedbeds following a variety of cutting methods and patterns.

Production of cones by old-growth trees in a nearly pure true fir forest was one of the earliest studies begun during the first cuttings at Swain Mountain (1958-60). Cones on tagged trees were counted annually for 16 years. Early results have been reported;[1] this note carries the record through 1975.

The study produced two useful findings:

- Red and white fir cone crops good enough to result in significant numbers of established seedlings occur most often at 1- or 2-year intervals, occasionally at 3-year intervals, and seldom at 4-year intervals.
- Such cone crop levels appear to have a threshold that can be determined from the mean cone production of selected trees; at Swain Mountain the mean was about 45 cones per old-growth tree. This value may apply only locally.

STUDY AREA

Swain Mountain Experimental Forest is mostly composed of varying mixtures of white fir (*Abies concolor* [Gord. and Glend.] Lindl.) and California red fir (*A. magnifica* A. Murr.). Scattered throughout are

single Jeffrey pines *(Pinus jeffreyi* Grev. and Balf.) and sugar pines *(P. lambertiana* Dougl.), and small stands or groups of lodgepole pine *(P. contorta* Dougl.). The Experimental Forest is typical of red fir sites, and only that species appears near the top of the mountain. Elevations range from 5700 to 7000 feet (1700 to 2100 m). Precipitation averages 40 to 50 inches (1016 to 1270 mm) a year, and is mainly snow. Snow surveys indicated a maximum pack of about 8 feet (2.4 m). Site quality is mostly II; dominant and codominant trees measure 100 feet (30 m) at 100 years.[2]

METHODS

Cones were counted on trees which met certain criteria: each tree selected was mature, dominant, apparently vigorous and free of defects, and had a pointed top. Because cones for each tree were to be counted consistently from a staked location about 1 to 2 tree-heights distant, visibility of the upper crown became a factor in selection. Also, the upper crown had to remain unobscured by growth of any trees for 10 years or more.

Twenty trees of each species were selected in 1960, a good seed year for red fir. Half of the trees of each species were located in the interior of stands, and half at the uncut edges of two clearcut strips — one 5 chains (100 m) wide, one 3 chains (60 m) wide. All trees were tagged, measured, and described to indicate location in the stand, and slope and aspect of the site; species, d.b.h., height, and age class; and crown class, vigor, and density. Tree diameters ranged from 32 to 55 inches (81.3 to 139.7 cm), and heights from 145 to 205 feet (44 to 62 m).

In 1971 and 1973 the study was slightly enlarged by the addition of immature age class trees (about 75 to 150 years old). A total of 10 white firs and 12 red firs were added, some located in dense even-aged stands, and some isolated in a brush field or in logged areas.

Each year, all visible cones were counted by one of two methods. In years when relatively few cones were produced, 6 × 30 binoculars mounted on a tripod were used. In years of cone abundance, color slides of tree crowns were obtained with a tripod-held 35-mm camera equipped with either a 300- or 400-mm telephoto lens.[3] For counting, images of trees with cones were projected on large sheets of paper in the office, and each cone location was marked with a felt-tip pen. Because of the image magnification obtained with the telephoto lens, a few trees required more than one photo for complete coverage of the cone-bearing part of the crown, but matching the telephoto projections of such trees in the office was readily done.

Field counts of cones customarily have been made with binoculars (in spite of real difficulties during years of abundance). For comparison, therefore, results of both counting methods which I used are reported here as if all counts were made using binoculars. (Counts from telephoto slides have been reduced by using a factor of 0.853 ; this had been developed in earlier studies because such counts were found to be considerably higher than binocular counts.)[3]

RESULTS AND CONCLUSIONS

The greatest number of cones for individual fir trees was recorded in 1971: 1314 for a white fir and 238 for a red fir.

Whenever the annual average number of cones per tree (of either species) fell below about 45, the comparative productivity from tree to tree was erratic, and half or more of the trees produced less than a dozen cones each. Also, in those years, the coefficient of variation of the count ranged as high as 75 to 180 percent of the mean. In years when the average per tree was more than 45 cones, the median coefficient of variation was about 65 percent of the mean.

After the 1958-60 and the 1970-72 cuttings at Swain Mountain, observations were made on receptive seedbeds in widely distributed cutting areas.[1,4] (Receptive seedbeds here are those not occupied by any plants or their root systems, nor covered by organic debris.) Few seedlings of either fir species became permanently established in the summer immediately following a fall season when cone production on count trees reached an average of less than 45. It was also observed[1] that cone- and seed-eating insects destroy proportionately greater amounts of fir seed in years of low cone production than in years of heavy crops, so that years when cone production is below such a "threshold" would be expected to be followed by even lower than normal seedling establishment.

The record of cone production over 16 years (fig. 1) shows that "establishment years" — those in which cone counts reached the threshold level — occurred at various intervals:

	Number of occurrences	
Interval:	*White fir*	*Red fir*
4 years	1	1
3 years	1	2
1 or 2 years	5	5

Establishment years were equal in number for the two species, but did not necessarily coincide. For each

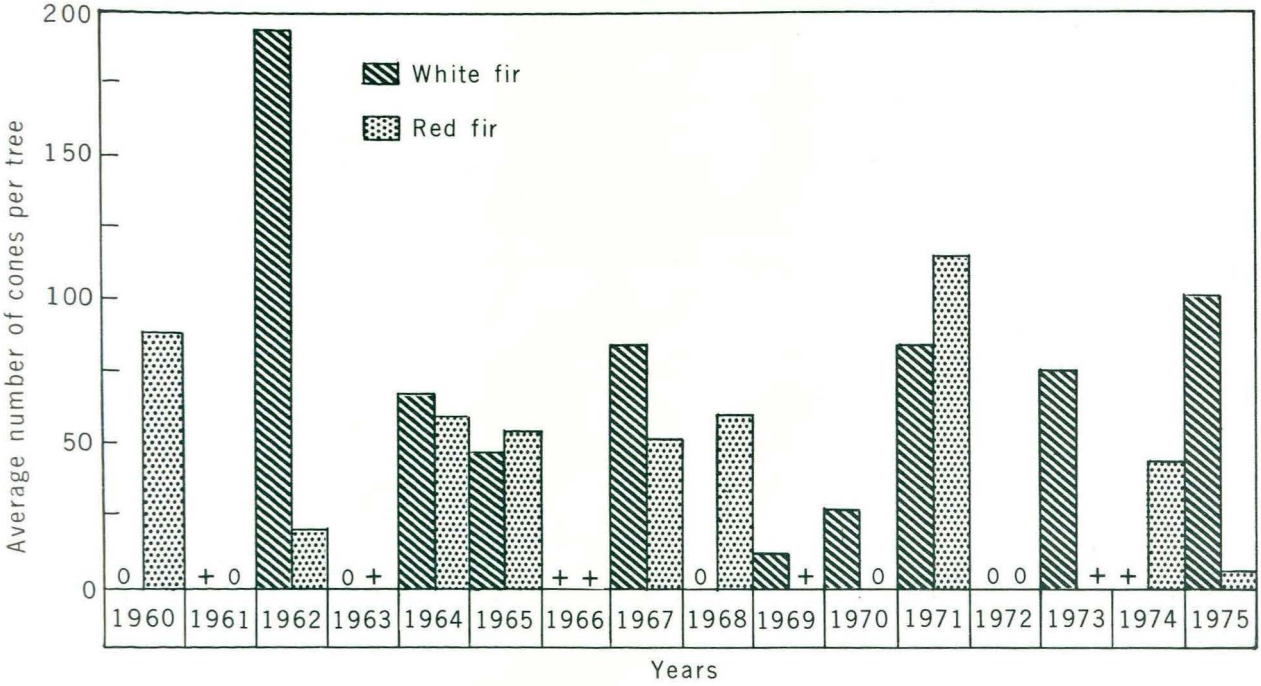

Figure 1—Average cone production per tree of 11 white firs and 11 red firs in 16 successive years, Swain Mountain Experimental Forest, California. + = only a few cones, 0 = none.

species, there were 7 of the 16 years when crops reached the 45-cone level, but only 4 years when this was true for both species. Similarly, there was only one period as long as 2 years in which neither species reached that level.

Cone production of trees at cutting edges created in 1958 can be compared with that of trees inside the stand in only a general way, because final sample sizes differed. Overall, white fir trees at edges (5 trees) produced 1.8 times as many cones per tree as interior trees (6). Red fir edge trees (3) produced 1.4 times as many cones as interior trees (8). But the trends of annual production differed greatly for the years in which one or both species exceeded 45 cones per tree:

	Ratio, edge/interior	
	White fir	*Red fir*
Year:		
1960	—	1.9
1962	1.5	—
1964	1.5	.9
1965	.6	1.0
1967	6.7	1.0
1968	—	.8
1971	2.2	2.1
1973	2.0	—
1974	—	1.3
1975	1.7	—

Nothing but very generalized trends should be inferred from these data: samples were small and there were no data on cone production of edge trees before cutting. In early results of this study (presented in a previous publication[1]), individual white firs appeared to be consistently good, medium, or poor cone producers. Red fir trees were rather erratic producers. Time has modified the early findings.

In one test 11 trees of each species were ranked on the basis of annual production in each of 16 years, and classified roughly as "good," "medium," or "poor." A chi-square test ($p = 0.05$) showed no difference between species in the distribution of trees in this ranking. The best and poorest producers of each species were ranked that way in half or more of the years of record. Trees having medium productivity ranked erratically, and red fir more so than white fir. Some trees of each species were lost to the study:

	Trees lost	
	White fir	*Red fir*
Cause:		
Top broken	2	4
Top died	2	0
Windthrown	2	3
"Died"	1	0
	7	7

Half of the 14 trees were lost through effects of the 1962 hurricane; a mortality level of that magnitude is unlikely to occur often elsewhere. The number of original trees of each species had to be reduced to 11 to get sample comparability for the full 16 years.

Since this study was started, additional progress has been made in identifying old-growth dominant firs which will not only produce enough seed to more than satisfy regeneration needs through different cutting systems, but also will successfully resist damage from normal storm winds.[4]

Cone production on immature age class trees was observed only for the periods of 3 and 5 years after they were added to the study. Results may indicate trends, however. Of the six trees added in 1971, four were red fir: these produced more cones per tree (144) than the mean for old red firs (116) in the "good" crop year of 1971. In 1974, a medium crop year, the same trees produced an average of 22 cones each, while the old trees produced about 45. No trends developed among young white firs during the study. (Fowells and Schubert[5] found that immature age class white firs produced cones abundantly during a long-term study.)

If observed cone production of 75-to-100-year-old firs continues to compare favorably with that of old growth, natural regeneration in the intensively-managed young fir stands of the future would be a good silvicultural option.

NOTES

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[5] Fowells, H.A., and G.H. Schubert. 1956. *Seed crops of forest trees in the pine region of California.* USDA Tech. Bull. 1150, 48 p., illus.

The Author

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GPO 971-9